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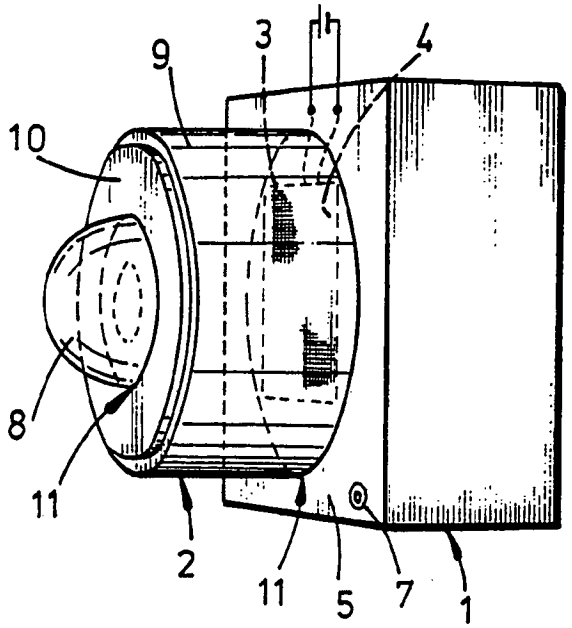

(57) Abstract

The present invention relates to a lens system (2) suitable for substantially direct interfacing with the image sensing surface (3) of a solid state image capture device (4). The lens system (2) comprises a lens (8) and a spacer (a) in substantially direct contact with each other. The spacer (9) preferably has a refractive index not less than that of said lens (8). The lens (8) and spacer (9) have refractive indices and are dimensioned so as to form an image in a plane at or in direct proximity to a rear face of the spacer (9) element remote from the lens (8) element, from an object. In use of the lens system (2) with the lens system (2) mounted substantially directly on the image sensing surface (3) of the image capture device (4) an optical image may be captured thereby. The present invention also relates to an image capture system including a lens system of the invention, which image capture is desirably provided with a video image display device and/or a video image recording device.

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LENS SYSTEM

The present invention relates to lens systems and in particular to a lens system suitable for substantially direct interfacing with solid state image capture devices.

Although various very compact solid state image capture devices are used in various types of optical apparatus such as video cameras and the like, these generally employ relatively cumbersome lens systems which require, moreover, more or less complex and cumbersome mounting and positioning means for aligning the image produced by the lens system onto the image sensing surface of the image capture device.

It is an object of the present invention to avoid or minimise one or more of the above disadvantages.

The present invention provides a lens system suitable for substantially direct interfacing with the image sensing surface of a solid state image capture device, which lens system comprises a lens and a spacer in substantially direct contact with each other, said lens and spacer having refractive indices and being dimensioned so as to form an image in a plane at or in direct proximity to a rear face of said spacer element remote from said lens element, from an object, whereby in use of the lens system with said lens system mounted substantially directly on the image sensing surface of the image capture device an optical image may be captured thereby.

Thus with a lens system of the present invention, the lens system may be mounted substantially directly on the image sensing surface of a solid state image capture device to provide a focussed image thereon without the

need for any complex positioning means and associated operations during manufacture of image capture systems. Furthermore by using suitable securing means e.g. suitable optical grade adhesive between the lens system and the solid state image capture device it will be appreciated that there may be provided image capture systems which are particularly resistant to rough handling which in conventional systems can result in misalignment of the lens system relative to the image capture device in use of such systems.

Thus in a further aspect the present invention comprises an image capture system comprising a lens system of the invention mounted substantially directly on the image sensing surface of a said solid state image capture device.

As used herein the expression "substantially direct contact" is used to mean that there should not be any significant interspace containing low refractive index material such as air i.e. no interspace having a thickness resulting in a significant optical effect. In the case of an air gap this should normally be not more than 500 μm, preferably not more than 100 μm, thick. In the case where resin or like material is used between the components adhesively to secure them together and has a refractive index comparable to that of the lens or spacer, it may be considered as an extension of the lens or spacer and thus need not be so restricted in thickness though preferably the thickness thereof should not be excessive and should be more or less similarly restricted.

Advantageously there is used a plano-convex (or possibly plano-concave - see below) lens with a substantially plane spacer for manufacturing convenience and economy

but other combinations e.g. a bi-convex lens and a plan-concave spacer, may also be used. Whilst a particular advantage of the inventin resides in the possibility of having a complete lens system directly attached to the sensing surface of a solid state image capture device, it will be appreciated that this invention is also applicable to complex lens systems with a plurality of separate lenses or lens system (e.g. where it is desired to hae one lens or lens system movable relative to another), wherein one lens system is attached to the sensing surface and the other part(s) is (are) mounted separately therefrom. In one example there could be used a field-flattening lens system comprising a plano-concave lens and spacer attached directly to the sensing surface of a solid state image capture device.

Preferably the lens system is secured to said image sensing surface by an optical grade adhesive i.e. a substantially transparent optically uniform adhesive. Desirably there is used between the lens and spacer an adhesive having the same refractive index as the lens (or if preferred, as a spacer) and between the spacer and the sensing surface, an adhesive having the same refractive index as the spacer.

Preferably the spacer has a higher, most preferably a substantially higher, refractive index than the lens. Where the same refractive index is acceptable for both then it will be appreciated that the spacer could be formed integrally with the lens.

It will be appreciated that the radius (or radii) of curvature of the lens element and its refractive index may be varied through a wide range of values depending on the required performance in terms of depth field,

image size, freedom from aberrations etc. In general there will desirably be used solid state image capture devices in the form of photoelectric sensor arrays (wherein photons are used to generate electric current and/or voltage or change electrical properties such as resistance etc.) which have relatively small size image sensing surfaces e.g. in the range from 0.1 to 5 cms across. Thus the lens system should in such cases desirably be formed and arranged to provide a similarly small-sized image. Where a wide angle filed of view is also required (e.g. in surveillance applications), then a lens of relatively short focal length should be used e.g. for a field of view angle of 80 degrees the (maximum) focal length will not normally exceed 1.19 times the image height and for 60 degrees will not normally exceed 1.73 times the (maximum) image height, the (maximum) image height corresponding to half the sensing surface diamater. The use of a high refractive index spacer and the exclusion of any low refractive index material from the optical path significantly decreases aberration due to Petzval Curvature (otherwise known as curvature of field aberration) and limits spherical aberration. The lens system is therefore particularly advantageous in wide field and/or large aperture applications required for low light conditions. In general there is desirably used, for such wide angle applications, a lens element having a refractive index n_d in the range from 1.45 to 1.65, and a spacer element with a higher, refractive index n_d in the range from 1.45 to 1.85.

Various optical grade materials having suitable refractive indices are widely available. Low-dispersion glass such as type BK7 (available from various sources e.g. Schott Glaswerke) is particularly suitable for the lens element. The spacer element may be made of LaK10

glass also readily available. Other materials that may be used for the lens and/or spacer elements comprise plastics materials, although these are generally less preferred in view of their lower resistance to scratching and other damage and the lower refractive indices available. Nevertheless they may be acceptable for certain applications requiring low cost such as consumer door-entry and security cameras.

Suitable adhesive materials for use between the spacer and lens elements and between the spacer element and the solid state image capture device include optical grade epoxy resins.

In the case of other applications such as video telephones, camcorders, electronic still cameras, and imaging systems for robots etc where narrower fields of view are acceptable then there may of course be used a lens and spacer with lower refractive index differential or even with equal refractive indices.

Preferably aperture stop means are provided between the lens and spacer in order further to limit spherical aberration and reduce coma and astigmatism, in generally known manner. Thus, for example, in the case of wide angle lens systems of the invention there is generally used a fixed aperture stop providing an f-number in the range from f/2 to f/22.

In a preferred image capture system of the present invention the solid state image capture device comprises an integrated circuit image array sensor such as that disclosed in our earlier International patent application No. PCT/GB90/01452 (publication No. WO 91/04633) which has on-board signal processing means formed and arranged for directly providing a video

signal output. Naturally though other image capture devices such as CCD, MOS and CID sensors may also be used.

Thus in another respect the present invention provides a video camera comprising an image capture system of the present invention provided with signal processing means formed and arranged for producing a video signal output.

Further preferred features and advantages of the present invention will appear from the following detailed description by way of example of a preferred embodiment illustrated with reference to the accompanying drawings in which:

Fig. 1 is a schematic perspective view of a video camera incorporating a lens system of the invention; and

Fig. 2 is a schematic view of the camera of Fig. 1 in use.

Fig. 1 shows a miniature video camera 1 comprising a lens system 2 mounted directly onto the image sensing surface 3 of a solid state image capture device in the form of an integrated circuit image array sensor 4. The sensor 4 is mounted in a suitable housing 5 containing a power supply 6 and provided with a video signal output interface 7.

In more detail the lens system 2 comprises a generally hemispherical lens 8 having a radius of curvature of the order of 0.8 mm, and a cylindrical spacer element 9 of substantially larger diameter (ca. 1.7mm) and a length of 1.59mm, with an aperture stop 10 therebetween. The aperture stop 10 is of metal e.g. steel alloy with a thickness of 0.15mm and an iris diameter of 0.8mm providing an effective lens aperture of f2.0. The aperture opening is filled with clear epoxy resin 11 having a refractive index substantially similar to that

of the lens 8 and secures the lens 8 and spacer 9 to each other and to the aperture stop 10.

The lens is of low dispersion glass Bk7) having a refractive index n_d of 1.568 and the spacer is of LaK10 glass which has a higher refractive index n_d of 1.7200. This combination produces low image blur and large image size (ca. 1.4mm image height from central axis). The spacer 9 has a length of around 1.59mm.

The abovedescribed lens system has an effective depth of field of from 2.0 cms to ∞ with a field of view angle of 90° and has an rms blur of around 5µm which is within the unit sensor pixel dimensions thereby providing a reasonably good video signal image output from the video signal output connection 7.

It will be appreciated that various modifications may be made to the above described embodiment without departing from the scope of the present invention. Thus for example the spacer element could be a composite element made up of a plurality of plane components. The lens element could also be composite though this would normally be less preferred due to the significantly increased complexity. The various surfaces of the lens system could moreover be provided with diverse coatings for e.g. reducing undesirable reflections and selective filtration of the incident light rays in generally known manner.

As shown in Fig. 2 the image capture device 4 is provided with a signal processing means 12, which conveniently (as noted above) may be in the form of on-board signal processing means in an integrated circuit image array sensor as described in our International Patent Publication No. WO91/04633, and

which provides a video signal output at a suitable socket 7. The camera 1 may be coupled by suitable connections 13 to a suitable VDU (visual display unit) 14 and/or a video image recording device 15 for recording on a video image storage medium in the form of a video tape 16, though naturally other suitable media such as discs may also be used.

CLAIMS

1. A lens system suitable for substantially direct interfacing with the image sensing surface (3) of a solid state image capture device (4), characterised in that said lens system (2) comprises a lens (8) and a spacer (9) in substantially direct contact with each other, said lens (8) and spacer (9) having refractive indices and being dimensioned so as to form an image in a plane at or in direct proximity to a rear face of said spacer (9) element remote from said lens (8) element, from an object, whereby in use of the lens system (2) with said lens system (2) mounted substantially directly on the image sensing surface of the image capture device (4), an optical image may be captured thereby.

2. A lens system as claimed in claim 1 which comprises a plano-convex lens (8) and a plane spacer (9).

3. A lens system as claimed in claim 1 which comprises a bi-convex lens (8) and a plano-concave spacer (9).

4. A lens system as claimed in any one of claims 1 to 3 wherein said spacer (9) has a refractive index not less than that of said lens (8).

5. A lens system as claimed in any one of claims 1 to 4 wherein said lens (8) has a refractive index n_d in the range of from 1.45 to 1.65.

6. A lens system as claimed in any one of claims 1 to 5 wherein said spacer (9) has a refractive index n_d in the range of from 1.45 to 1.85.

7. A lens system as claimed in any one of claims 1 to 6 wherein said lens system is secured to said image sensing surface by a substantially transparent optically uniform adhesive.

8. A lens system as claimed in claim 7 wherein said adhesive has a refractive index the same as at least one of said spacer (9) and said lens (8).

9. A lens sytem as claimed in any one of claims 1 to 8 having an aperture stop (10) with an f-number in the range of from f2 to f22.

10. An image capture system comprising a lens system (2) according to claim 1 mounted substantially directly on the image sensing surface (3) of a solid state image capture device (4).

11. A camera comprising an image capture system according to claim 10 provided with signal processing means (12) formed and arranged for producing an output signal suitable for at least one of driving a video image display device (15) and recording of a video image in a video image storage medium (17).

12. A camera as claimed in claim 10 wherein said signal processing means (12) is coupled (13) to at least one of a video image display device (15) and a video image recording device (16).

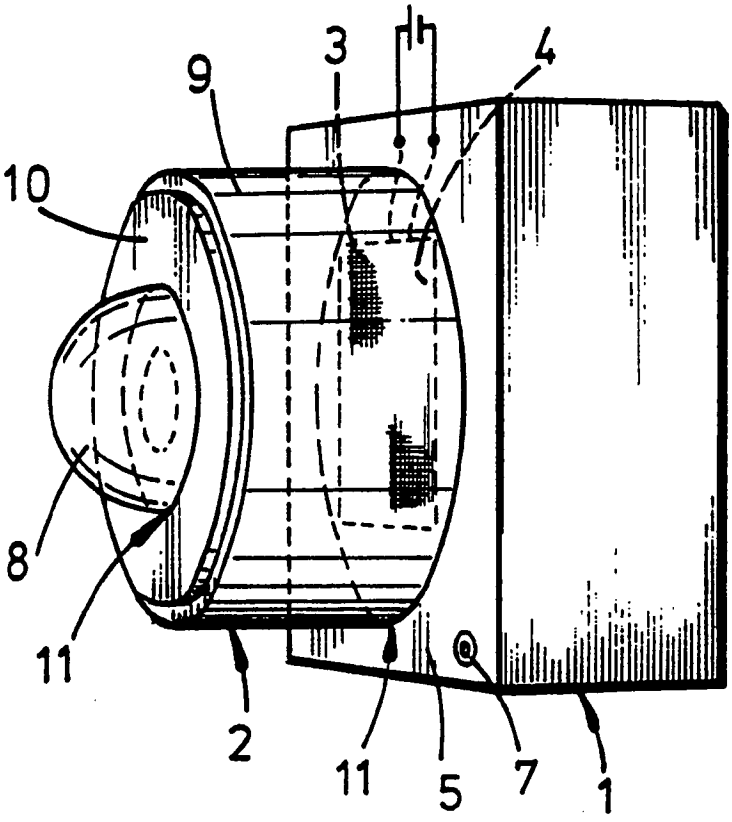

FIG. 1

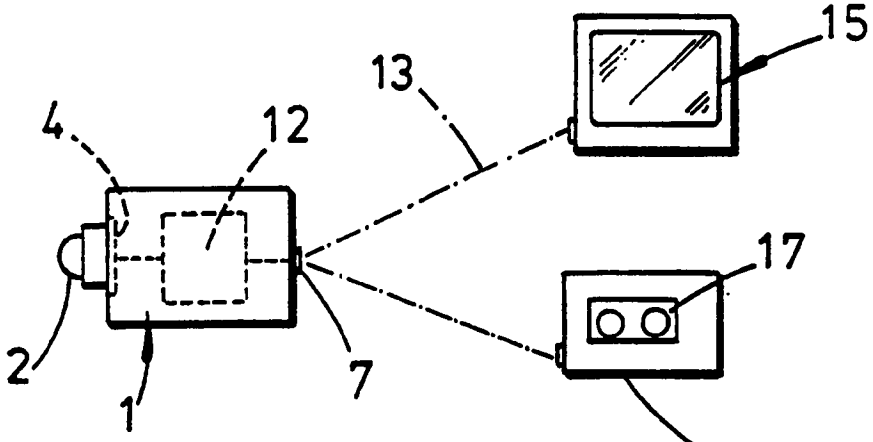

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 92/00299

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[5]: G 02 B 13/16

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[5]	G 02 B 13/00,G 03 B 7/00,H 04 N 3/00,H 04 N 9/00

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	US, A, 4 303 322 (SOMEYA) 01 December 1981 (01.12.81), see fig 1; column 3, lines 13-40. --	1
A	JP, A, 02-161 412 (CANON) 21 June 1990 (21.06.90), see the whole document. --	1
A	US, A, 4 992 875 (SHINTANI et al.) 12 February 1991 (12.02.91), see fig. 2; column 3, lines 54-58. ----	1

* Special categories of cited documents: [14]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
08 May 1992	21. 05. 92
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	Natalie Weinberg

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ANHANG — ANNEX — ANNEXE

zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.

to the International Search Report to the International Patent Application No.

au rapport de recherche international relatif à la demande de brevet international n°

PCT/GB 92/00299 SAE 56841

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In Recherchenbericht angeführtes Patentdokument Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
US A 4303322	01-12-81	keine - none - rien	
JP A2 2161412	21-06-90	US A 5086338 JP A2 2141090	04-02-92 30-05-90
US A 4992875	12-02-91	JP A2 2094976 JP A2 2094975 JP A2 2029083	05-04-90 05-04-90 31-01-90